United States Patent [19]

Lent et al.

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[45] **Date of Patent: May 29, 1990**

[54] **CONTROL SYSTEM FOR A ROAD PLANER**

[75] Inventors: **Kevin C. Lent,** Maple Grove; **Conwell K. Rife, Jr.,** Champlin, both of Minn.; **Gerald P. Simmons,** Morton; **Albert J. Speck,** Springfield, both of Ill.

[73] Assignee: **Caterpillar Paving Products Inc.,** Minneapolis, Minn.

[21] Appl. No.: **403,270**

[22] Filed: **Sep. 5, 1989**

[51] **Int. Cl.**[5] **E01C 23/12**

[52] **U.S. Cl.** **404/84;** 299/1; 299/39; 404/90; 474/110

[58] **Field of Search** 404/84, 90, 122; 299/39, 1; 474/101, 110; 307/39

[56] **References Cited**

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4,139,318 2/1979 Jakob et al. 404/90

4,406,354 9/1983 Barsted .... 299/1 X

4,473,319 9/1984 Spangler .... 404/84 X

4,655,634 4/1987 Loy et al. 404/84

4,780,022 10/1988 Ohiba et al. .... 404/84 X

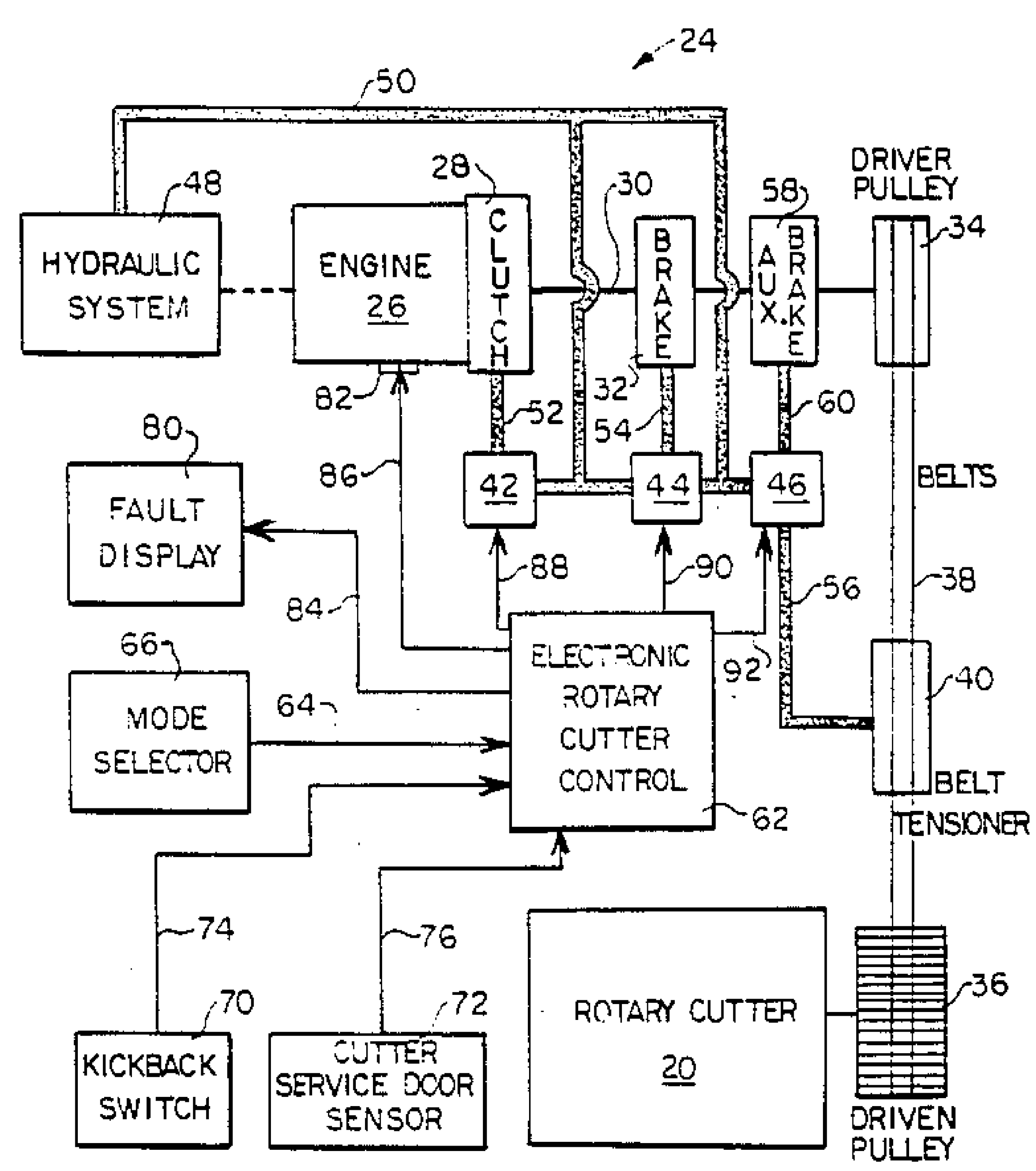
Primary Examiner—Stephen J. Novosad

Attorney, Agent, or Firm—Robert A. McFall

[57] **ABSTRACT**

A control system for a road planer in which the mechanical drive components are selectively and sequentially controlled in response to operator inputs and to sensed operating conditions. The control also responds to the occurrence of predefined fault events and internal system failures by controlling the operation of one or more of the mechanical drive line components in a preselected order. Suitable time delays are provided between the execution of selected commands to prevent undesirable wear or loads on components of the drive train.

14 Claims, 12 Drawing Sheets



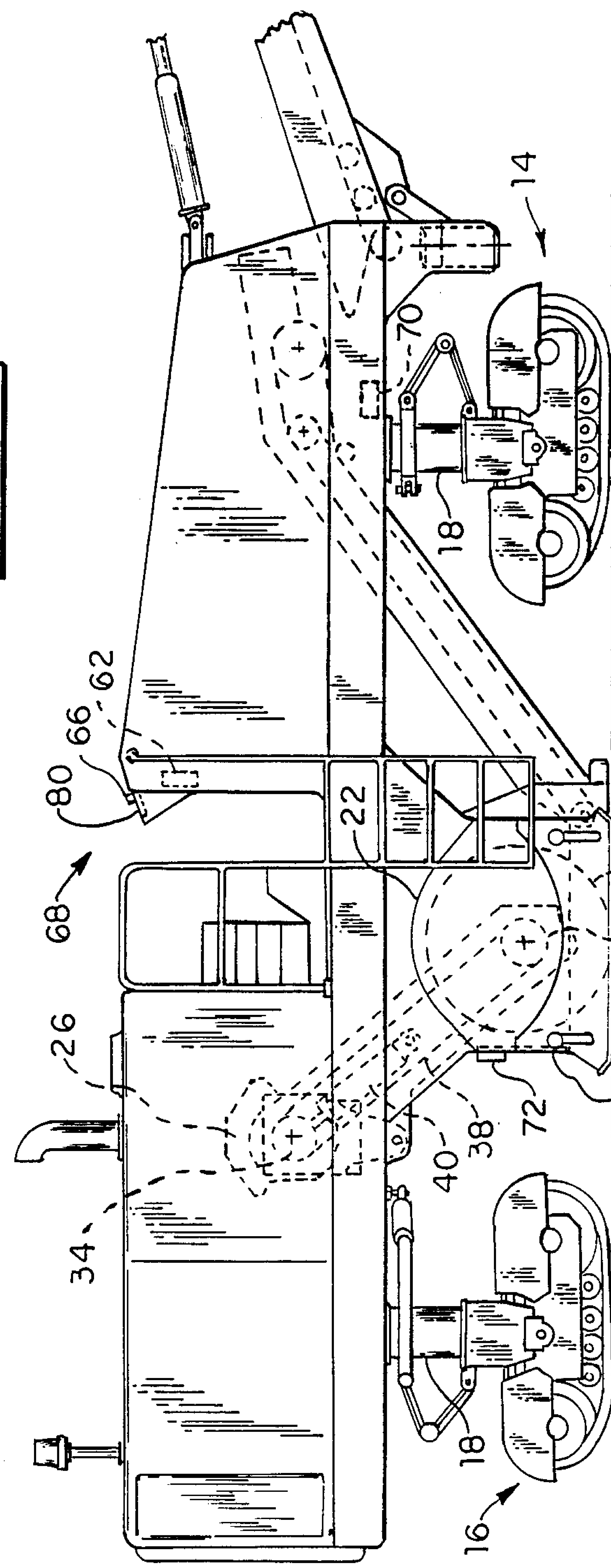
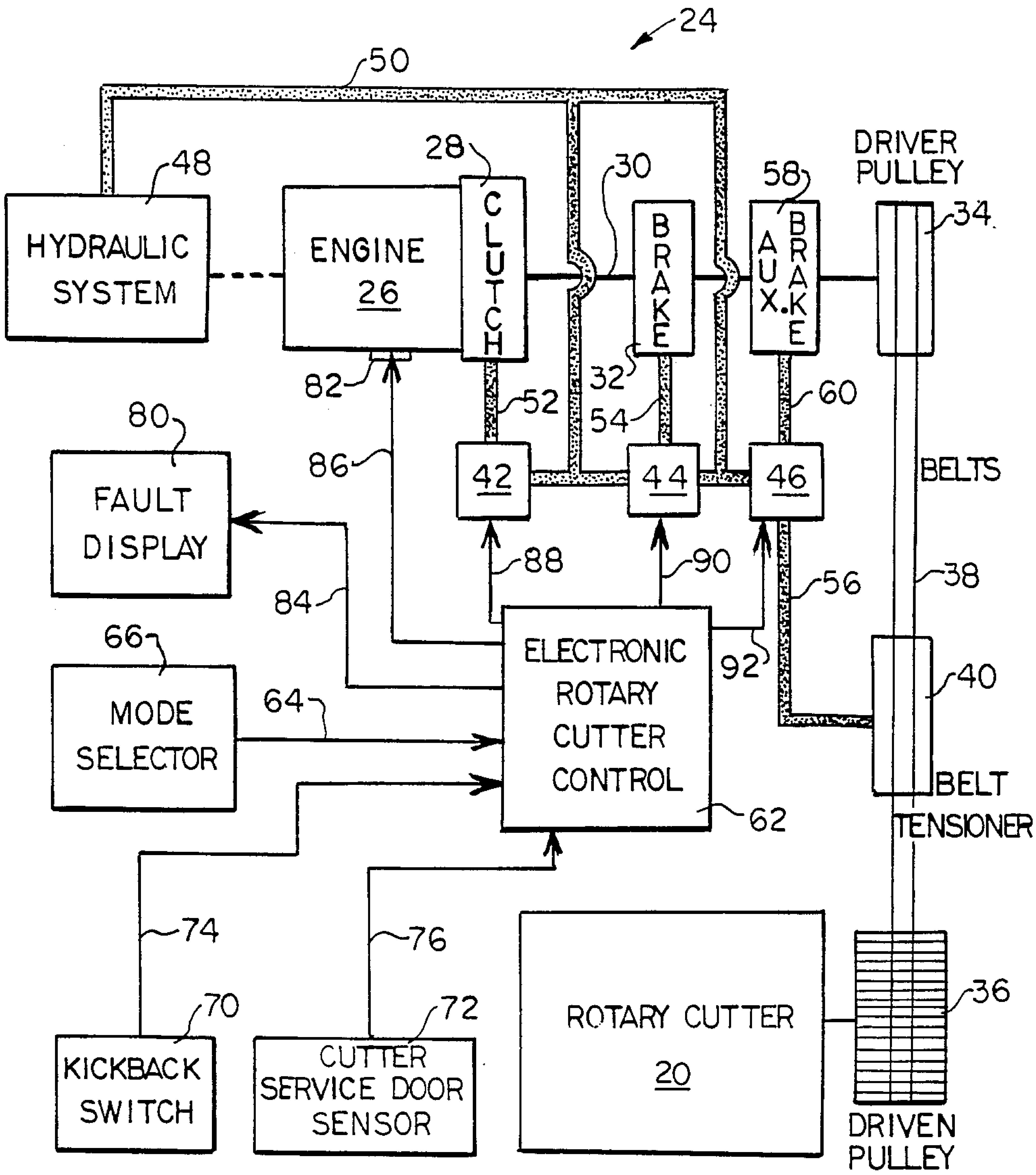


FIG-1

Fig. 2.


24
50
48
HYDRAULIC SYSTEM
ENGINE 26
28
CLUTCH
30
BRAKE
58
AUX. BRAKE
DRIVER PULLEY
34
82
32
52
54
60
80
FAULT DISPLAY
86
42
44
46
BELTS
88
90
56
38
84
ELECTRONIC ROTARY CUTTER CONTROL
92
40
66
MODE SELECTOR
64
BELT TENSIONER
62
74
76
ROTARY CUTTER 20
36
70
72
KICKBACK SWITCH
CUTTER SERVICE DOOR SENSOR
DRIVEN PULLEY

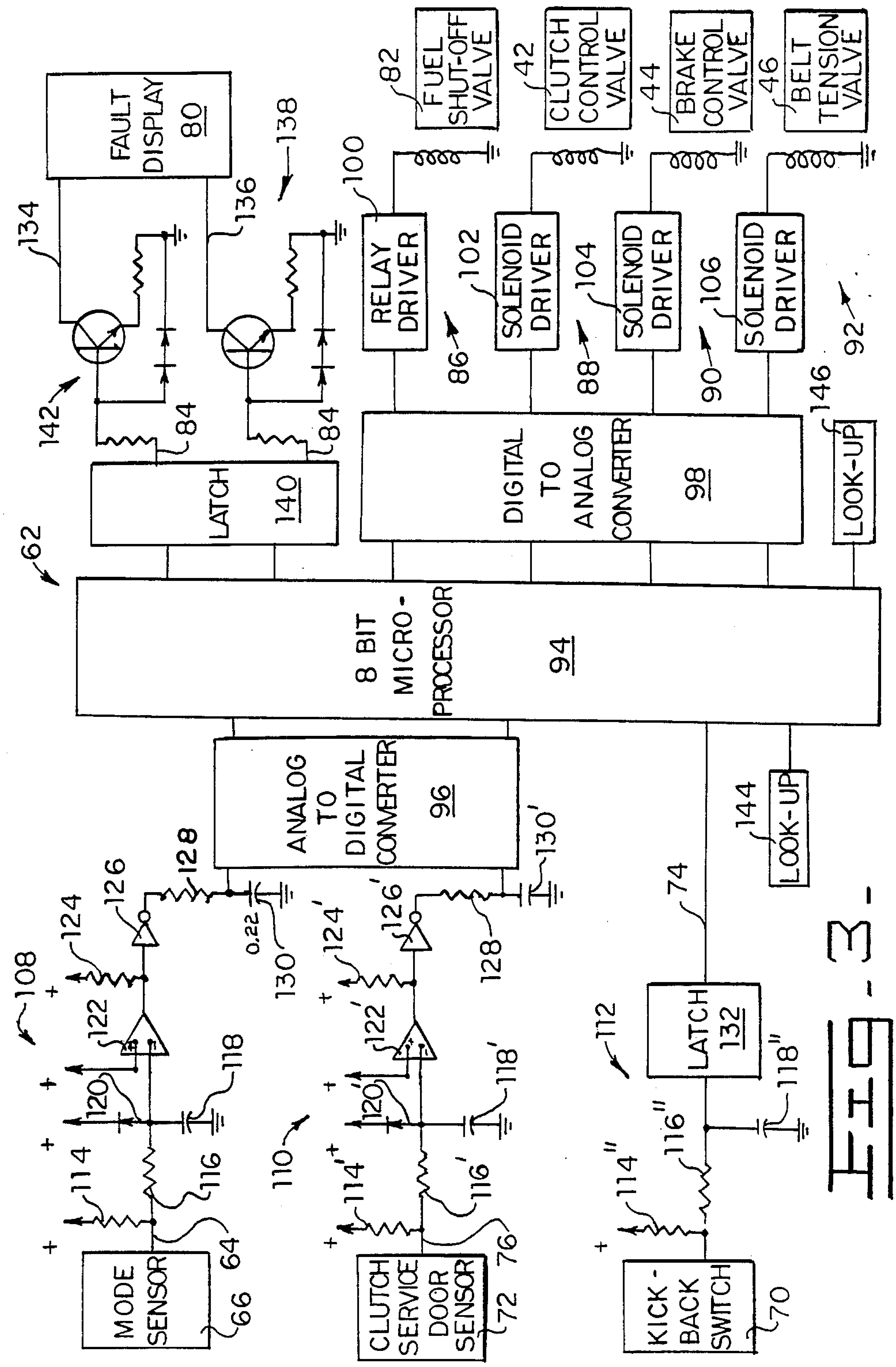

FAULT DISPLAY 80
LATCH 140
RELAY DRIVER
SOLENOID DRIVER
SOLENOID DRIVER
SOLENOID DRIVER
FUEL SHUT-OFF VALVE
CLUTCH CONTROL VALVE
BRAKE CONTROL VALVE
BELT TENSION VALVE
DIGITAL TO ANALOG CONVERTER 98
LOOK-UP
8 BIT MICRO-PROCESSOR 94
ANALOG TO DIGITAL CONVERTER 96
LOOK-UP
LATCH 132
MODE SENSOR
CLUTCH SERVICE DOOR SENSOR
KICK-BACK SWITCH
0.22

FIG-3

FIG. 4

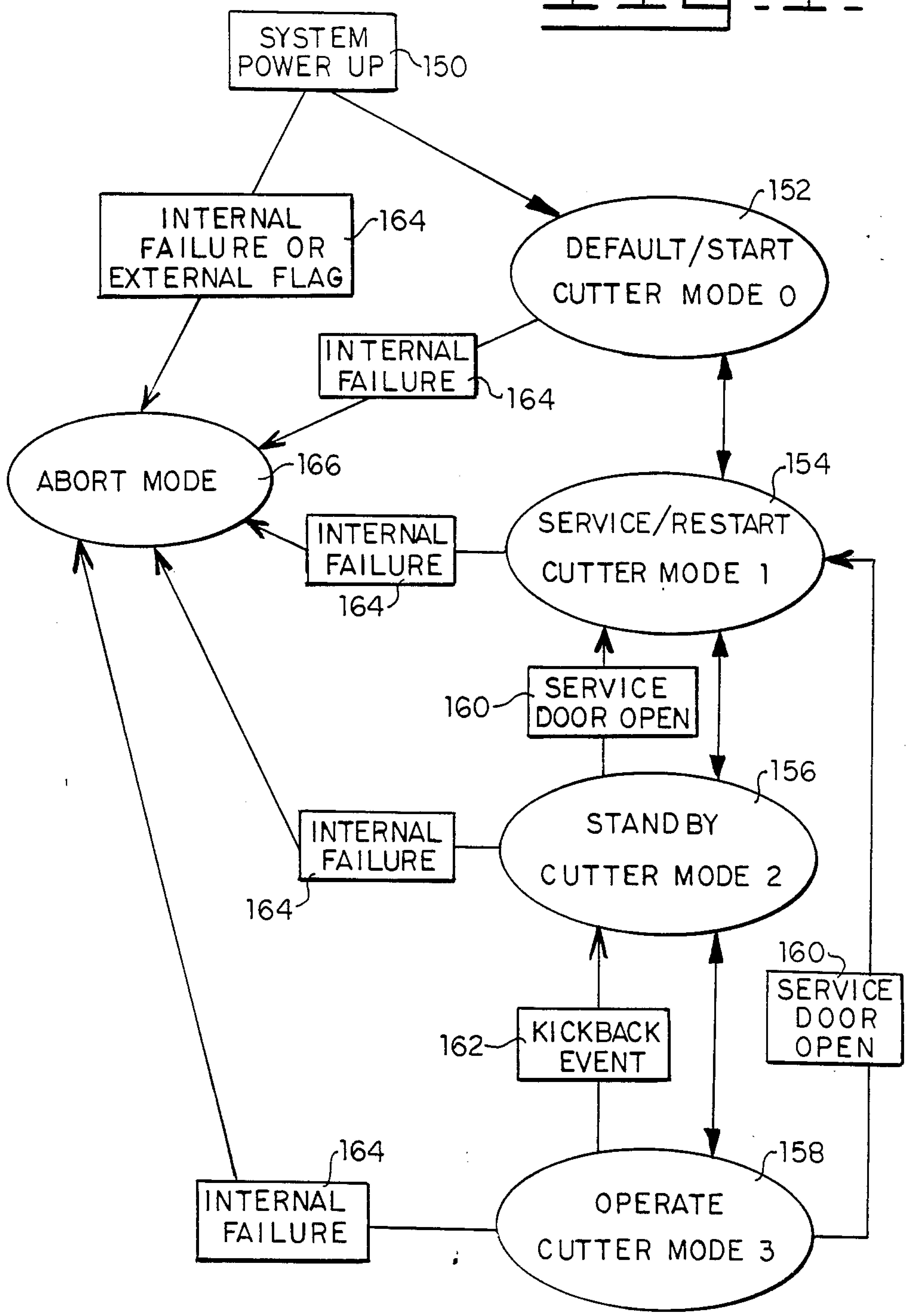

SYSTEM POWER UP
150
INTERNAL FAILURE OR EXTERNAL FLAG
164
152
DEFAULT/START CUTTER MODE 0
INTERNAL FAILURE
164
ABORT MODE
166
154
SERVICE/RESTART CUTTER MODE 1
INTERNAL FAILURE
164
160
SERVICE DOOR OPEN
156
STAND BY CUTTER MODE 2
INTERNAL FAILURE
164
160
SERVICE DOOR OPEN
162
KICKBACK EVENT
164
158
INTERNAL FAILURE
OPERATE CUTTER MODE 3

FIG. 5.

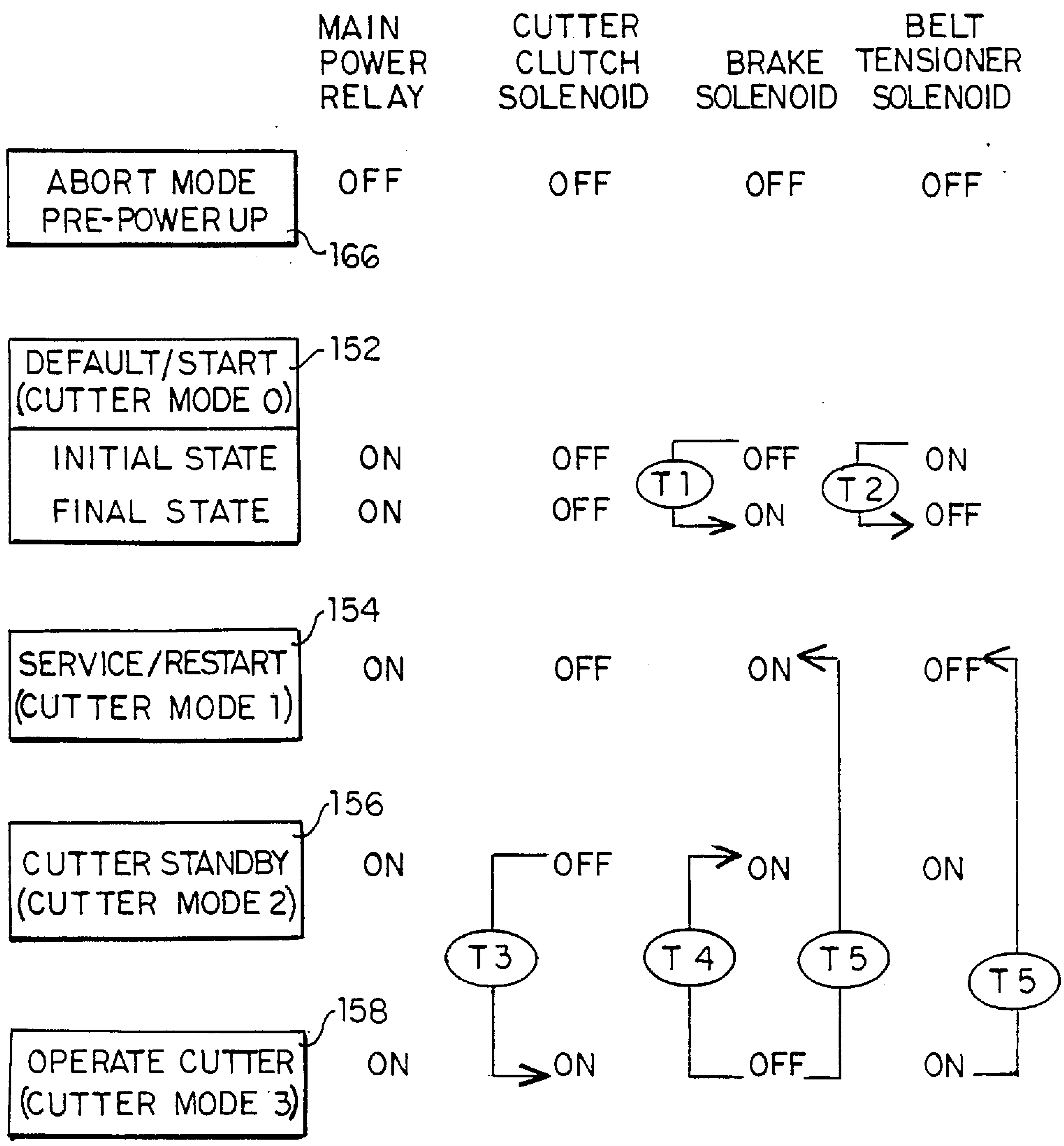

MAIN POWER RELAY
CUTTER CLUTCH SOLENOID
BRAKE SOLENOID
BELT TENSIONER SOLENOID
ABORT MODE PRE-POWER UP
OFF
OFF
OFF
OFF
166
DEFAULT/START (CUTTER MODE 0)
152
INITIAL STATE
FINAL STATE
ON
ON
OFF
OFF
T1
OFF
ON
T2
ON
OFF
154
SERVICE/RESTART (CUTTER MODE 1)
ON
OFF
ON
OFF
156
CUTTER STANDBY (CUTTER MODE 2)
ON
OFF
ON
ON
T3
T4
T5
T5
158
OPERATE CUTTER (CUTTER MODE 3)
ON
ON
OFF
ON

FIG. 6

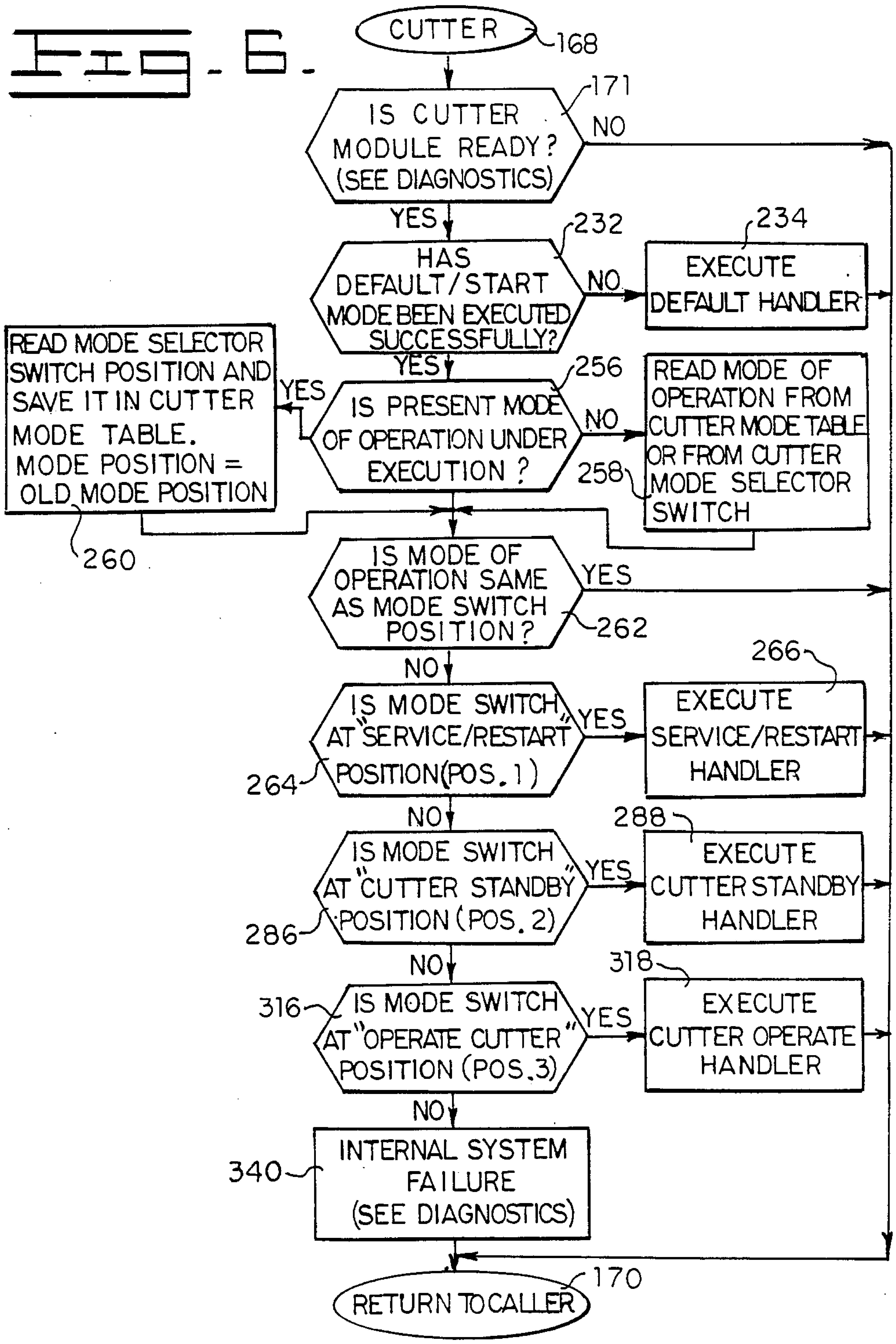

CUTTER
168
171
IS CUTTER MODULE READY? (SEE DIAGNOSTICS)
NO
YES
232
HAS DEFAULT/START MODE BEEN EXECUTED SUCCESSFULLY?
NO
234
EXECUTE DEFAULT HANDLER
YES
256
IS PRESENT MODE OF OPERATION UNDER EXECUTION ?
YES
READ MODE SELECTOR SWITCH POSITION AND SAVE IT IN CUTTER MODE TABLE. MODE POSITION = OLD MODE POSITION
260
NO
READ MODE OF OPERATION FROM CUTTER MODE TABLE OR FROM CUTTER MODE SELECTOR SWITCH
258
IS MODE OF OPERATION SAME AS MODE SWITCH POSITION?
YES
262
NO
266
IS MODE SWITCH AT "SERVICE/RESTART" POSITION(POS. 1)
264
YES
EXECUTE SERVICE/RESTART HANDLER
NO
288
IS MODE SWITCH AT "CUTTER STANDBY" POSITION (POS. 2)
286
YES
EXECUTE CUTTER STANDBY HANDLER
NO
318
316
IS MODE SWITCH AT "OPERATE CUTTER" POSITION (POS.3)
YES
EXECUTE CUTTER OPERATE HANDLER
NO
340
INTERNAL SYSTEM FAILURE (SEE DIAGNOSTICS)
170
RETURN TO CALLER

FIG. 7.

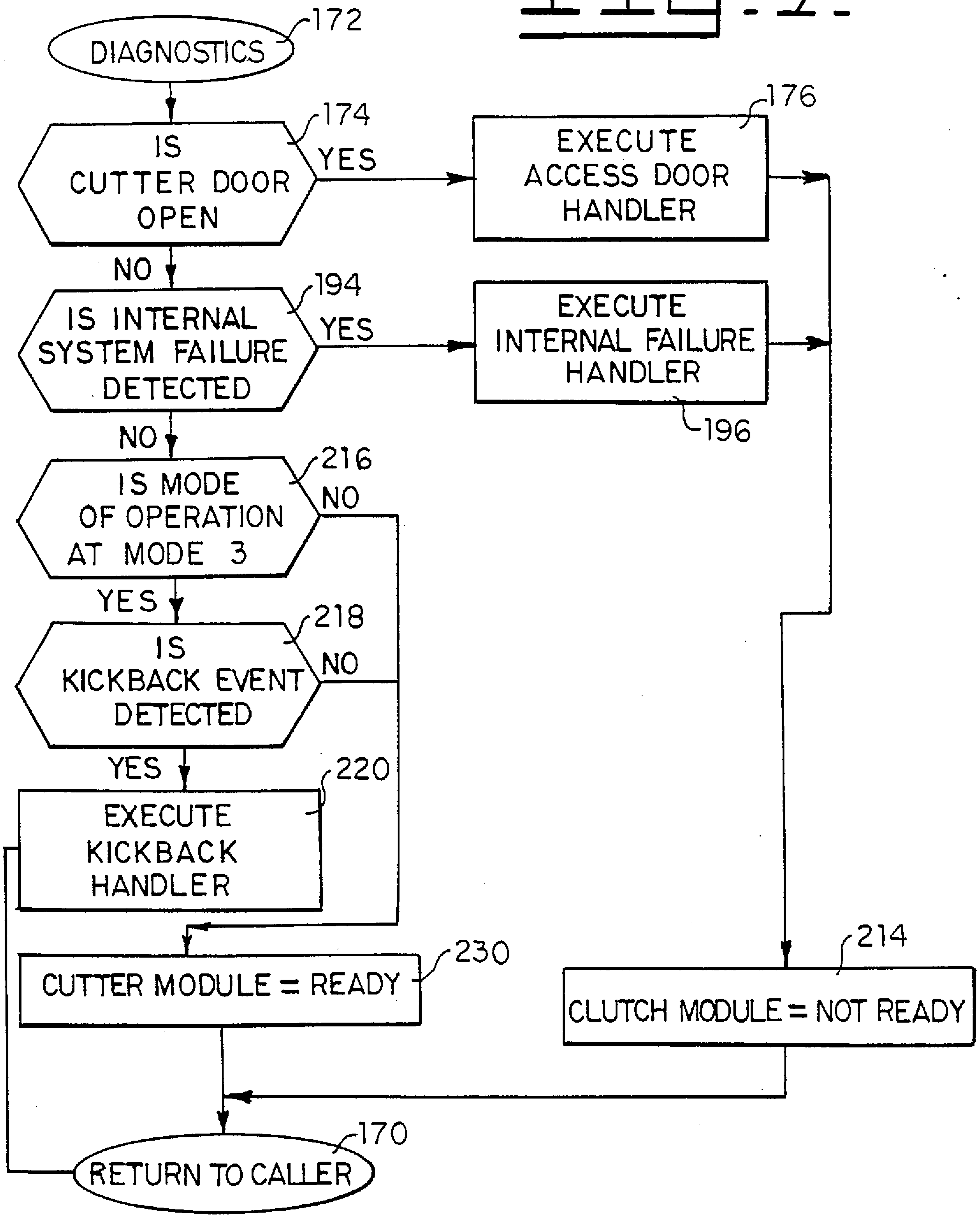

DIAGNOSTICS
172
IS CUTTER DOOR OPEN
174
YES
NO
EXECUTE ACCESS DOOR HANDLER
176
IS INTERNAL SYSTEM FAILURE DETECTED
194
YES
NO
EXECUTE INTERNAL FAILURE HANDLER
196
IS MODE OF OPERATION AT MODE 3
216
NO
YES
IS KICKBACK EVENT DETECTED
218
NO
YES
EXECUTE KICKBACK HANDLER
220
CUTTER MODULE = READY
230
CLUTCH MODULE = NOT READY
214
RETURN TO CALLER
170

FIG-8-

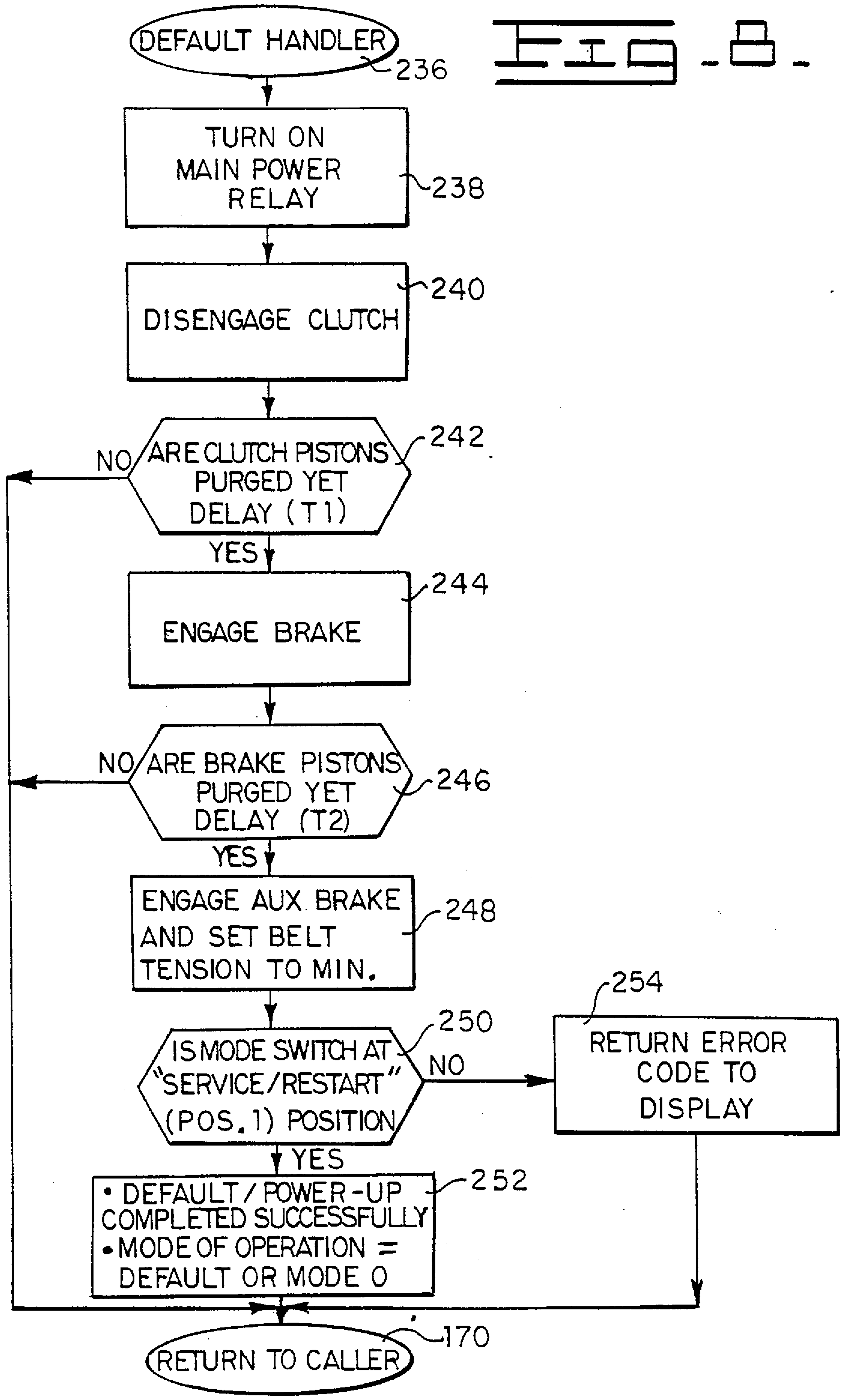

DEFAULT HANDLER
236
TURN ON MAIN POWER RELAY
238
DISENGAGE CLUTCH
240
ARE CLUTCH PISTONS PURGED YET DELAY (T1)
242
NO
YES
ENGAGE BRAKE
244
ARE BRAKE PISTONS PURGED YET DELAY (T2)
246
NO
YES
ENGAGE AUX. BRAKE AND SET BELT TENSION TO MIN.
248
IS MODE SWITCH AT "SERVICE/RESTART" (POS. 1) POSITION
250
NO
YES
RETURN ERROR CODE TO DISPLAY
254
• DEFAULT/POWER-UP COMPLETED SUCCESSFULLY
• MODE OF OPERATION = DEFAULT OR MODE 0
252
RETURN TO CALLER
170

FIG. 9.

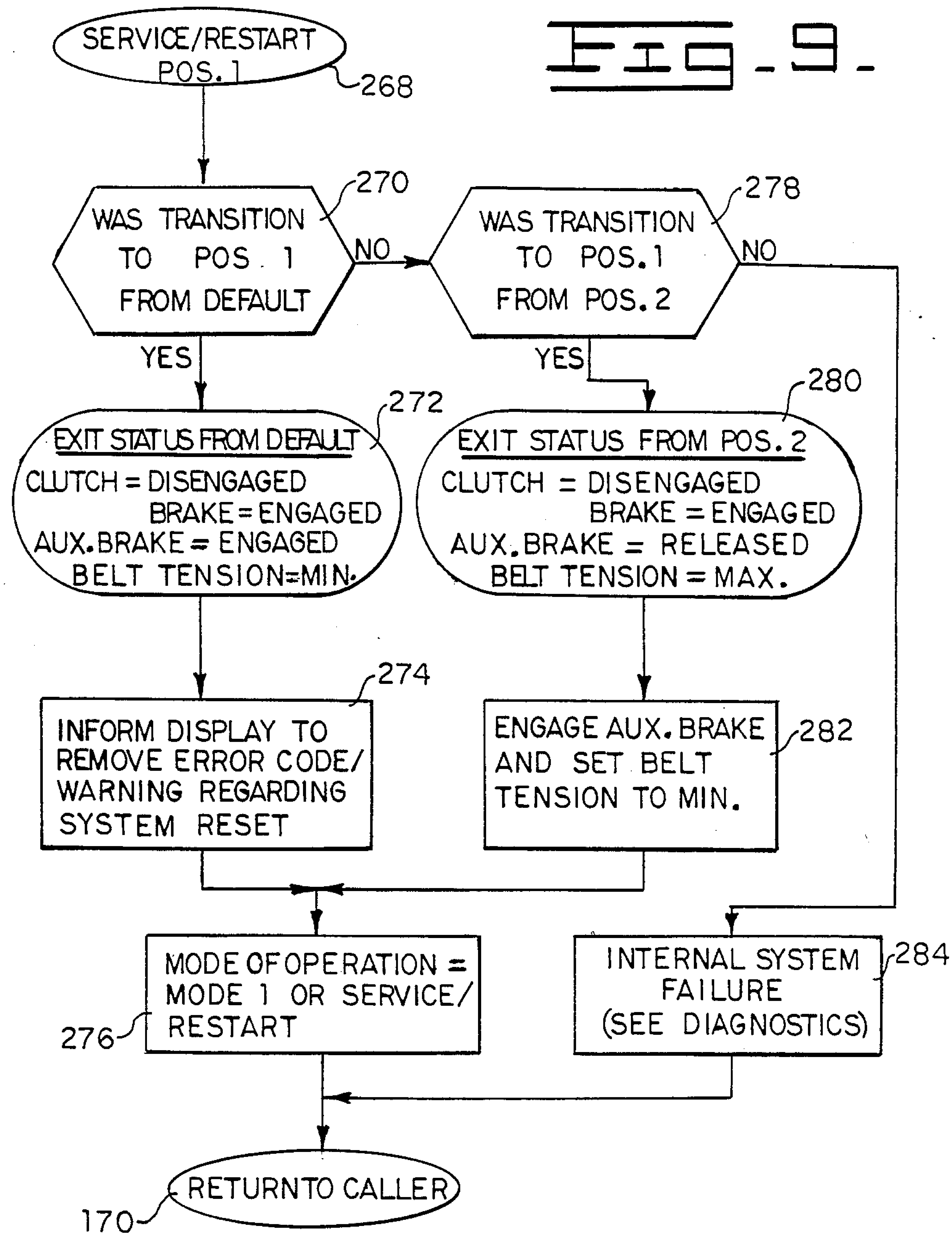

SERVICE/RESTART POS. 1
268
WAS TRANSITION TO POS. 1 FROM DEFAULT
270
NO
YES
WAS TRANSITION TO POS. 1 FROM POS. 2
278
NO
YES
EXIT STATUS FROM DEFAULT
CLUTCH = DISENGAGED
BRAKE = ENGAGED
AUX. BRAKE = ENGAGED
BELT TENSION = MIN.
272
EXIT STATUS FROM POS. 2
CLUTCH = DISENGAGED
BRAKE = ENGAGED
AUX. BRAKE = RELEASED
BELT TENSION = MAX.
280
INFORM DISPLAY TO REMOVE ERROR CODE/ WARNING REGARDING SYSTEM RESET
274
ENGAGE AUX. BRAKE AND SET BELT TENSION TO MIN.
282
MODE OF OPERATION = MODE 1 OR SERVICE/ RESTART
276
INTERNAL SYSTEM FAILURE (SEE DIAGNOSTICS)
284
RETURN TO CALLER
170

FIG. 10.

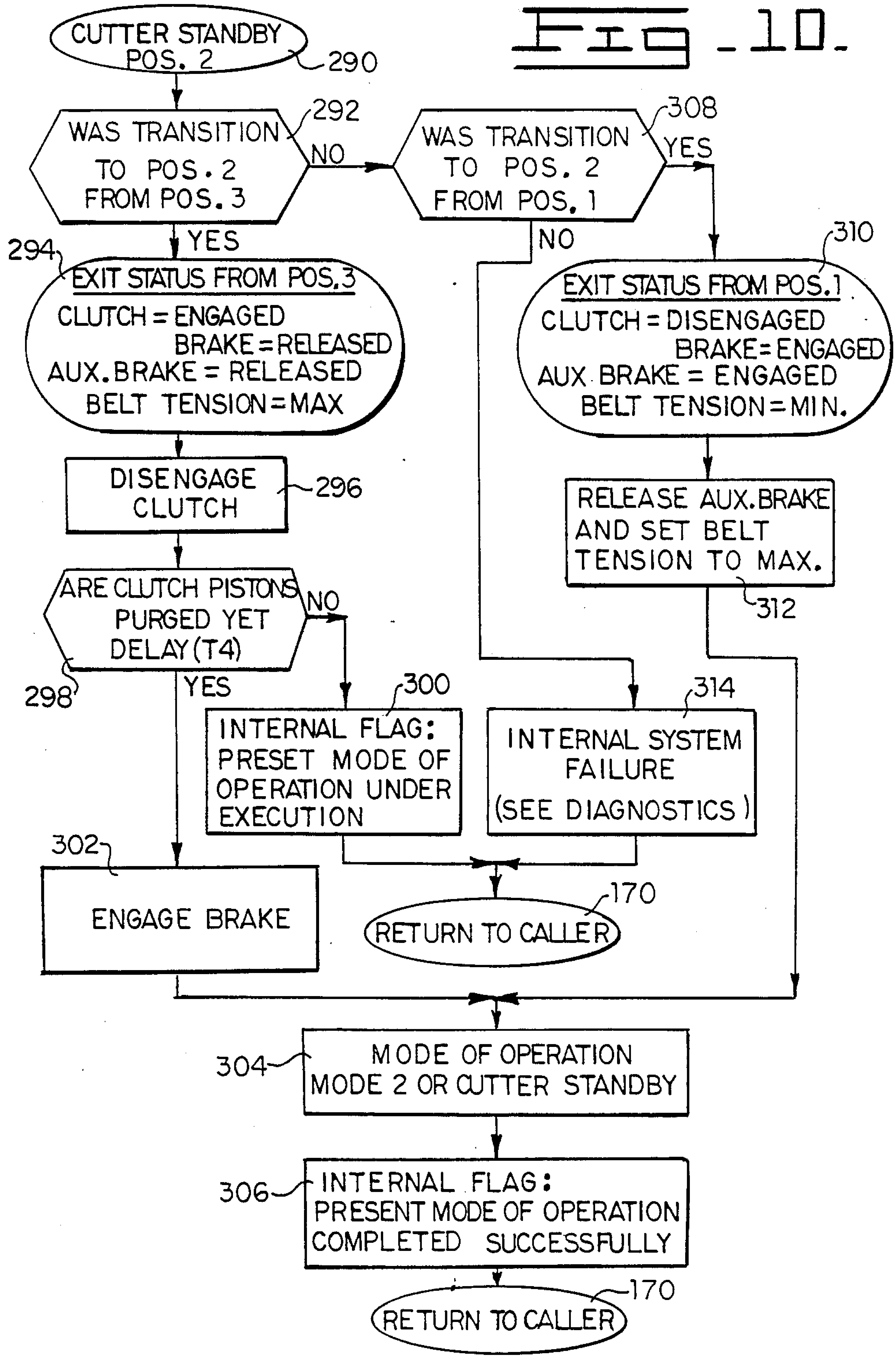
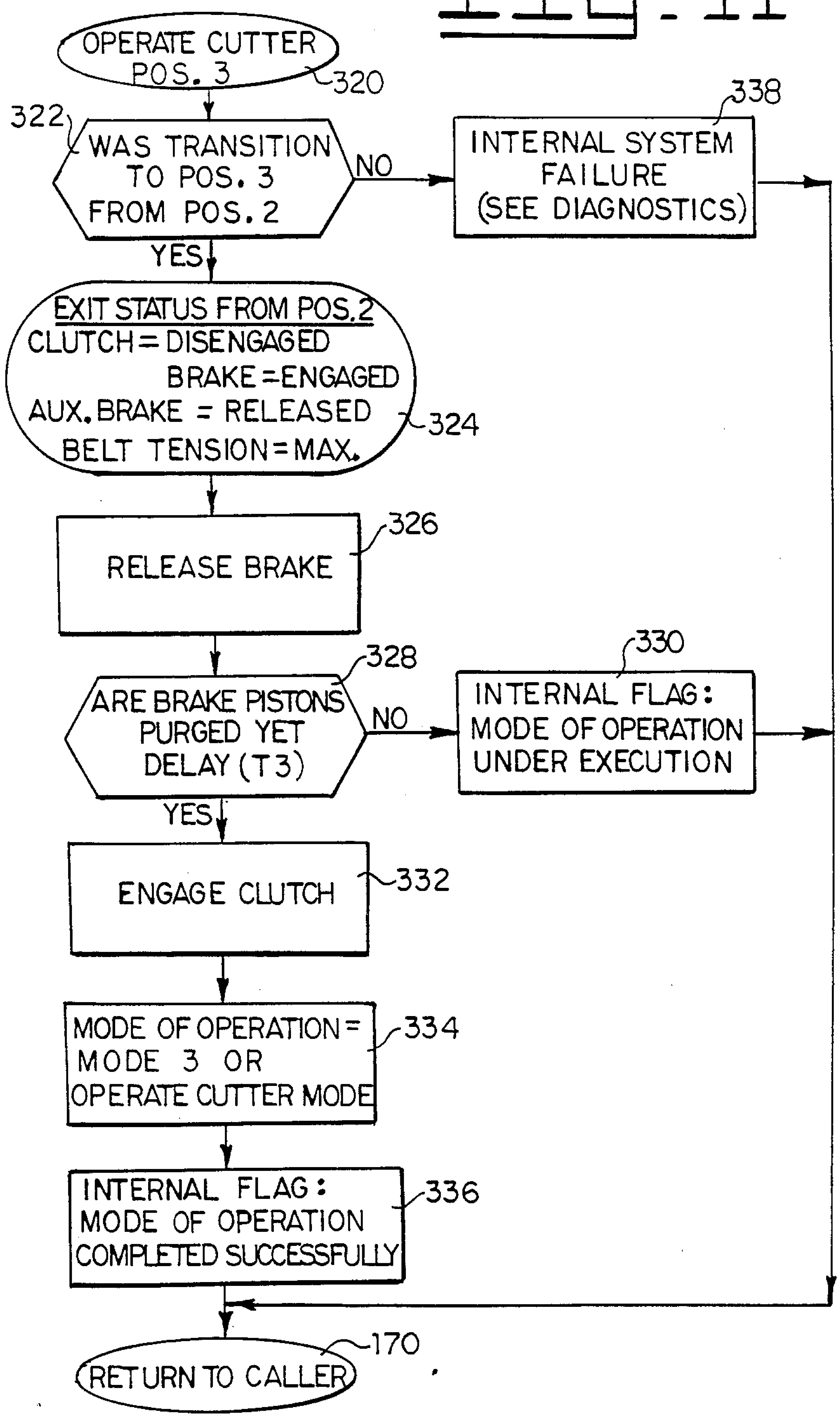

CUTTER STANDBY POS. 2
290
WAS TRANSITION TO POS. 2 FROM POS. 3
292
NO
YES
WAS TRANSITION TO POS. 2 FROM POS. 1
308
YES
NO
294
EXIT STATUS FROM POS.3
CLUTCH = ENGAGED
BRAKE = RELEASED
AUX. BRAKE = RELEASED
BELT TENSION = MAX
310
EXIT STATUS FROM POS.1
CLUTCH = DISENGAGED
BRAKE = ENGAGED
AUX. BRAKE = ENGAGED
BELT TENSION = MIN.
DISENGAGE CLUTCH
296
RELEASE AUX. BRAKE AND SET BELT TENSION TO MAX.
312
ARE CLUTCH PISTONS PURGED YET DELAY (T4)
NO
YES
298
300
INTERNAL FLAG: PRESET MODE OF OPERATION UNDER EXECUTION
314
INTERNAL SYSTEM FAILURE (SEE DIAGNOSTICS)
302
ENGAGE BRAKE
170
RETURN TO CALLER
304
MODE OF OPERATION MODE 2 OR CUTTER STANDBY
306
INTERNAL FLAG: PRESENT MODE OF OPERATION COMPLETED SUCCESSFULLY
170
RETURN TO CALLER

Fig. 11



OPERATE CUTTER POS. 3
320
322
WAS TRANSITION TO POS. 3 FROM POS. 2
NO
YES
338
INTERNAL SYSTEM FAILURE (SEE DIAGNOSTICS)
EXIT STATUS FROM POS. 2
CLUTCH = DISENGAGED
BRAKE = ENGAGED
AUX. BRAKE = RELEASED
BELT TENSION = MAX.
324
RELEASE BRAKE
326
328
ARE BRAKE PISTONS PURGED YET DELAY (T3)
NO
YES
330
INTERNAL FLAG: MODE OF OPERATION UNDER EXECUTION
ENGAGE CLUTCH
332
MODE OF OPERATION = MODE 3 OR OPERATE CUTTER MODE
334
INTERNAL FLAG: MODE OF OPERATION COMPLETED SUCCESSFULLY
336
RETURN TO CALLER
170

FIG. 12.

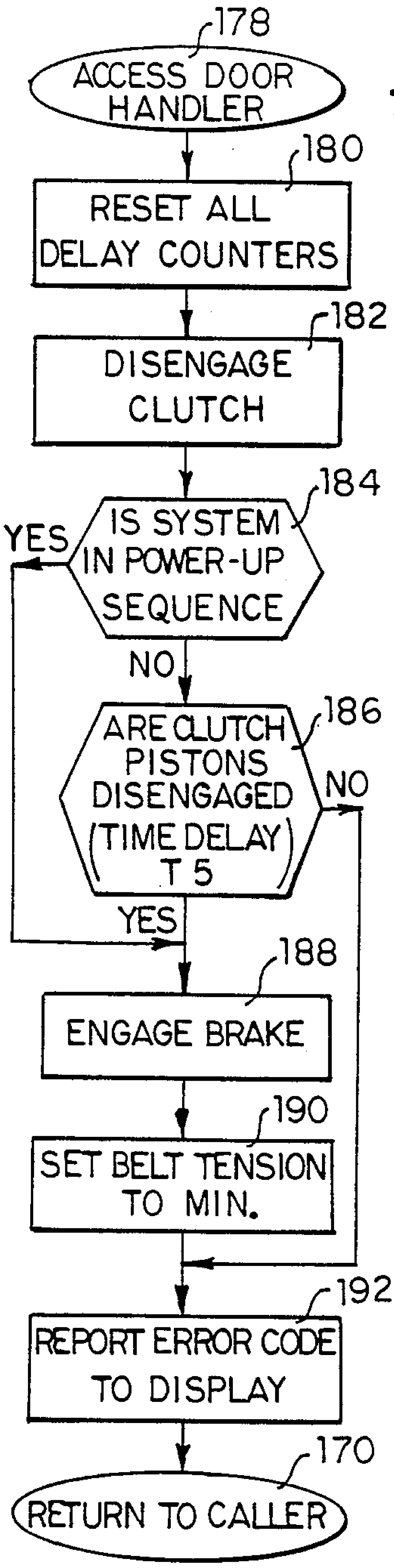


FIG. 14.

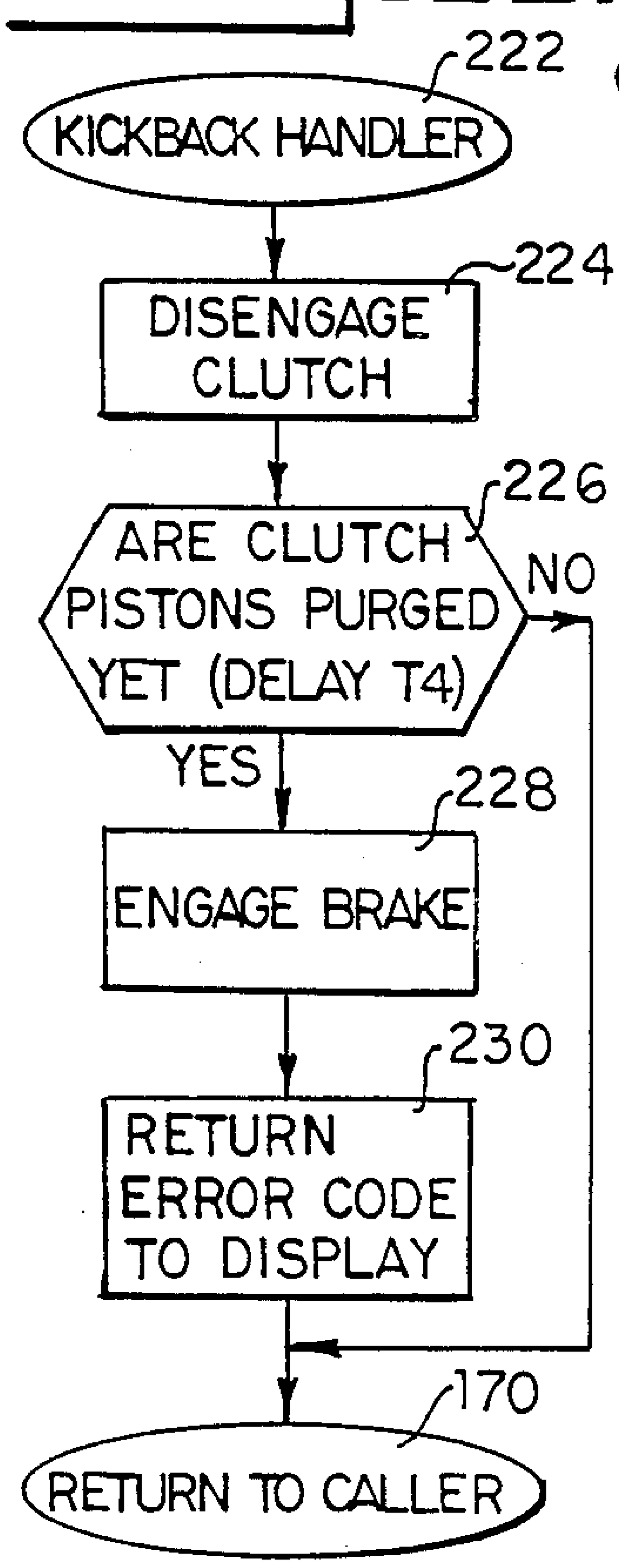
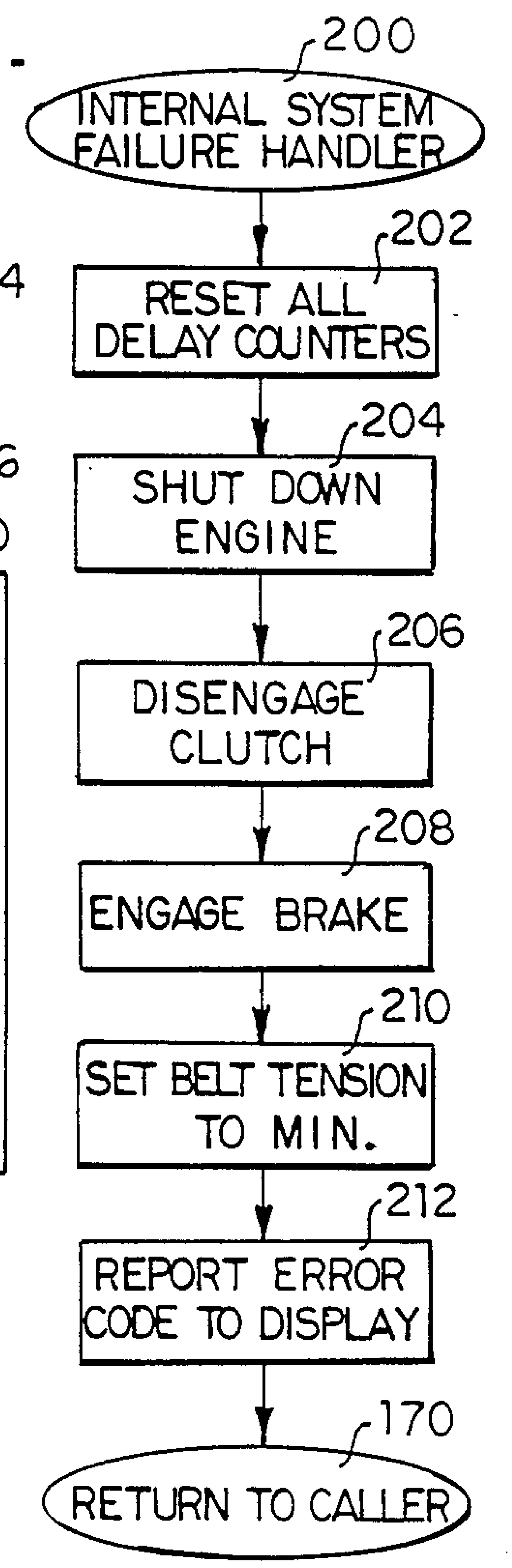


FIG. 13.



CONTROL SYSTEM FOR A ROAD PLANER

DESCRIPTION

1. Technical Field

This invention relates generally to a control system for the rotary cutter of a road planer and more particularly to a control system for a road planer having a mechanically driven rotary cutter.

2. Background Art

Road planers, also known as pavement profilers, road milling machines or cold planers, are machines designed for scarifying, removing, mixing or reclamation, of material from the surface of bituminous or concrete roadways and similar surfaces. These machines typically have a plurality of tracks or wheels which support and horizontally transport the machine along the surface of the road to be planed, and have a rotatable cutter that is vertically adjustable with respect to the road surface.

The rotatable cutter may be driven hydraulically by a remotely powered fluid motor or directly through a drive train mechanically connecting the cutter to an engine. A control system for a road planer having a hydraulically driven rotary cutter is described in U. S. Pat. No. 4,655,634, issued April 7, 1987 to Robert E. Loy et al. This reference describes an electrical circuit which is interrupted when an access door on the rotary cutter is opened. When the electrical circuit is interrupted, the cutter is prevented from rotating and the machine cannot be moved.

However, hydraulically powered motor systems are typically less efficient in transmitting power to the cutter than mechanical drive arrangements which directly connect the cutter to the engine. Mechanical drive arrangements are also particularly suited for mounting the cutter directly on the frame of the road planer. Mounting of the cutter, or more specifically the cutter bearing housings, directly on the vehicle frame provides rigidity between the cutter and the machine suspension system thereby minimizing undesirable deflection of the cutter during the surface milling or planing operation. For these reasons, it is desirable to mount the rotatable cutter and the engine driving the cutter directly on the vehicle frame and provide a direct mechanical drive between the engine and the cutter.

Heretofore, mechanically driven cutters have been coupled to the engine by a belt drive arrangement that typically includes an air operated clutch connecting the engine output shaft to a drive pulley. The drive pulley is linked to a driven pulley on the cutter mandrel by a plurality of v-belts. Tension in the v-belts is provided by manually adjusting an idler pulley or, alternatively, manually repositioning the drive pulley with respect to the driven pulley. Often, it is necessary to slacken or remove tension from the v-belts to facilitate replacement of individual cutting tools or otherwise service the rotary cutter. Heretofore, this has required manual adjustment of the belt tensioning mechanism.

The present invention is directed to overcoming the problems set forth above. It is desirable to have a mechanically driven rotary cutter in which the v-belt drive component is selectively and automatically tensioned or slackened. It is also desirable to have a system for controlling the mechanical drive system so that preselected components of the system, including the automatic belt tensioning mechanism, are engaged in a preselected sequential order in response to one or more control signals.

DISCLOSURE OF THE INVENTION

In accordance with one aspect of the present invention, a control system for a road planer having a cutter rotatably mounted on the planer and an engine operatively connected to the cutter, includes a clutch operatively connected to the engine, a brake operatively connected to an output shaft extending from the clutch, a pulley operatively connected to the clutch output shaft and a second pulley connected to the rotatably mounted cutter. An endless belt extends between the pulleys, and a mechanism is provided for tensioning the belt and urging it into driving contact with both of the pulleys. The clutch, brake and belt tensioning mechanism each have a control to govern their respective operations. These operational controls are, in turn, automatically controlled by a control that, in response to receiving a specific operating mode command signal, appropriately regulates one or more of the operational controls in a preselected sequential order.

Other features of the control system include a sensor capable of sensing at least one operating condition and delivering a corresponding signal to the control regulating the operation of the respective clutch, brake and belt tensioning controls.

Another feature of the control system includes an auxiliary brake interposed the first mentioned brake and the pulley operatively connected to the output shaft. The auxiliary brake is operatively controlled by the control for the belt tensioning mechanism.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of a road planer having a control system embodying the present invention;

FIG. **2** is a schematic diagram showing principal elements of the control system embodying the present invention;

FIG. **3** is a diagram showing the electrical circuit of the control system embodying the present invention;

FIG. **4** is a logic diagram showing the transitional interrelationship of the operating modes;

FIG. **5** is a diagram showing the programmed time delays during transition between operating modes;

FIG. **6** is a flow diagram showing the cutter control logic sequence;

FIG. **7** is a flow diagram showing the diagnostic logic sequence;

FIG. **8** is a flow diagram showing the default logic sequence;

FIG. **9** is a flow diagram showing the Service/Restart mode logic sequence;

FIG. **10** is a flow diagram showing the Cutter Standby mode logic sequence;

FIG. **11** is a flow diagram showing the Cutter Operating mode logic sequence;

FIG. **12** is a flow diagram showing the Access Door logic sequence;

FIG. **13** is a flow diagram showing the Internal System Failure logic sequence; and

FIG. **14** is a flow diagram of the Kickback logic sequence.

BEST MODE FOR CARRYING OUT THE INVENTION

A road planer, generally indicated by the reference numeral **10**, comprises a frame **12** that is carried for movement along a road surface by a pair of front track assemblies **14** and a pair of rear track assemblies **16**. The frame **12** is supported on the track assemblies **14,16** by a hydraulically actuated adjustable strut **18** extending respectively between each of the track assemblies and the frame. A rotary cutter **20** is rotatably mounted on the frame **12** and has a housing **22** surrounding all but the bottom of the cutter **20** which is necessarily exposed to the road surface. With the cutter **20** mounted directly to the frame **12**, the vertical relationship of the rotary cutter **20** with respect to the road surface, i.e., the depth of cut or penetration of the cutting teeth carried on the cutter **20** into the ground, is controlled by appropriate extension or retraction of one or more of the adjustable struts **18**. The road planer **10** also includes an engine **26** as a source of power to drive the rotary cutter **20**. The engine **26** is mechanically connected to the rotary cutter **20** by a direct mechanical drive arrangement.

In the preferred embodiment of the present invention, shown schematically in FIG. **2**, a control system **24** for the rotary cutter **20** of the road planer **10** comprises a hydraulically actuated wet disc clutch **28** directly connected to the engine **26** and an output shaft **30** extending from the clutch **28**. A hydraulically actuated brake **32** and a first, or drive, pulley **34** are operatively connected to the output shaft **30**. A second, or driven, pulley **36** is connected directly to the mandrel of the rotary cutter **20**, and an endless belt **38**, preferably a single joined v-belt or a plurality of separate v-belts, extends between the first and second pulleys **34,36**.

Means for tensioning the endless belt **38**, for the purpose of urging the belt into driving contact with both pulleys **34,36**, is provided by a hydraulically actuated belt tensioner **40**. The belt tensioner **40** may be a conventional idler pulley that is selectively urged to and held, by a hydraulic cylinder, in a position that effectively increases the distance between the pulleys **34,36**. Alternatively, the output shaft **30** may include one or more universal joints that permit the first pulley to be adjustably positioned with respect to the second pulley **36**. In this arrangement, an extensible hydraulic cylinder having one end attached to the frame **12** and a second end attached to a non-rotating bearing housing supporting the first pulley, may be selectively extended to increase the actual distance between the first and second pulleys **34,36**.

Control means for selectively engaging and disengaging clutch **28**, selectively applying and releasing the brake **32**, and selectively engaging and releasing the belt tensioner **40** are provided, respectively, by solenoid operated hydraulic flow control valves **42, 44** and **46**. A hydraulic system **48** provides a source of pressurized fluid to each of the flow control valves **42, 44** and **46** through a conduit **50**. Conduits **52, 54** and **56**, communicating respectively between the clutch control valve **42** and the clutch **28**, the brake control valve **44** and the brake **32**, and the belt tensioner control valve **46** and the belt tensioner **40**, direct the flow of pressurized fluid to the clutch, brake and belt tensioner.

Preferably, the mechanical drive train connecting the rotary cutter **20** the engine **26** includes an auxiliary brake operatively connected to the output shaft **30** and disposed between the primary brake **32** and the first pulley **34**. The auxiliary brake is desirably a spring actuated, hydraulically released brake. A conduit **60** provides fluid communication between the auxiliary brake **58** and the belt tensioner hydraulic flow control valve **46**. Hence, in the preferred embodiment, a flow of pressurized hydraulic fluid is supplied simultaneously to the auxiliary brake **58** and the belt tensioner **40** when the belt tensioner control valve is open to the supply conduit **50**, thereby concurrently tensioning the v-belts **38** and releasing the auxiliary brake **58**. When the belt tension control valve is closed, or the flow of pressurized fluid to the auxiliary brake and the belt tensioner **40** otherwise interrupted such as by equipment power failure, tension in the v-belts **38** is relaxed and the spring actuated auxiliary brake **50** is applied.

Operation of the clutch control means **42**, the brake control means **44**, and the belt tensioner control means **46** is governed by an electronic rotary cutter control **62**. The electronic rotary cutter control **62** is preferably mounted in a protective enclosure on the road planer **10** and controls one or more of the control means **42, 44, 46** in a preselected sequential order in response to receiving an output signal from a switch or sensor.

Specifically, an operating mode signal **64** is developed and delivered to the electronic control **62** by a mode selector switch **66** positioned at an operator's station **68** on the road planer **10**. Preferably, the mode selector switch **66** is a rotary switch developing a pulse-width modulated signal corresponding to a selected operating mode. In the preferred embodiment illustrative of the present invention, the mode selector switch **66** has, in addition to an off position, three detent positions corresponding to first, second and third operating modes. The first operating mode is a service or restart mode in which the clutch **28** is disengaged, the brake is applied, and belt tension is released. In the second operating mode, designated as a standby mode, the clutch **28** and the brake **32** remain in their first mode state, i.e., respectively disengaged and applied, but the belt tensioner control valve **46** is opened thereby applying tension to the v-belts **38** and releasing the auxiliary brake **58**. In the third, or normal, operating mode the belt tension control valve remains open, the brake **32** is released, and the clutch is engaged. Thus, in the third mode, the rotary cutter **20** is mechanically linked to the engine **26** and power is transferred directly from the engine to the rotary cutter.

Preferably, additional control signals representative of selected vehicle operating conditions are developed and delivered to the electronic rotary cutter control **62**. In the preferred embodiment representative of the present invention, a kickback switch **70** and a cutter service door position sensor **72** respectively develop and deliver a kickback event signal **74** and a service door position signal **76**.

The kickback switch **70** is a pressure switch sensing fluid pressure in the hydraulic circuit regulating the height of the adjustable strut **18** attached to at least one of the front track assemblies **14**. If, during a planing operation, the cutter **20** encounters a hard object or material and begins to ride up, i.e., rise out of the cut, an automatic level control on the road planer, not shown, will attempt to correct the attitude of the planer **10**. As a result, the automatic level control will reduce pressure in the circuits controlling extension of the struts **18** connecting the front track assemblies **12** to the vehicle frame **12**. When the pressure drops below a predetermined value in the front strut hydraulic circuit, the kickback switch **70** is triggered, thereby producing the kickback event signal **74**.

The service door position sensor **72** is mounted on a panel **78** covering an access opening in the cutter housing **22**. The service door position sensor **72** is preferably a rotary switch producing a pulse-width modulated analog signal corresponding to the position of the panel **78** with respect to the cutter housing **22**.

The control system **24** also includes a fault display **80** and a fuel shut-off valve **82**. The fault display is preferably a monitor or liquid crystal display mounted on a panel at the operator's station **68**. The fuel shut-off valve is preferably a solenoid actuated valve positioned in the fuel supply line to the engine **26**. Control signals **84, 86, 88, 90, 92** are developed by the electronic rotary cutter control **62** and delivered, respectively, to the fault display **80**, fuel shut-off valve **82**, clutch control valve **42**, brake control valve **44**, and belt tension control valve **46**.

The electronic rotary cutter control **62**, shown schematically in FIG. **3**, comprises a Motorola **6809** 8-bit programmable microprocessor **94**, and an analog to digital converter **94** for converting the pulse-width modulated analog input signals **64, 76** to digital signals. The electronic cutter control **62** also includes a digital to analog convertor **98** for converting the digital output of the microprocessor **94** to the analog control signals **86,88,90,92** delivered respectively to a relay driver **100** controlling the operation of the fuel shut-off valve **82**, and to solenoid drivers **102, 104, 106** controlling the operation, respectively, of the clutch control valve **42**, the brake control valve **44**, and the belt tension valve **46**.

The electronic rotary cutter control **62** also includes signal conditioning circuits **108, 110**, for regulating and filtering the pulse-width modulated operating mode signal **64** and service door position signal **76**, respectively, and an input signal conditioning circuit **112** for filtering and latching the kickback event signal **74**.

Specifically, each of the signal conditioning circuits **108, 110, 112** includes a respective pull-up resistor **114, 114', 114''** connected between the associated sensor and a +14 volt supply source. The pulse-width modulated signal conditioning circuits **108, 110** also include R/C filters connected respectively from the mode sensor **66** and the clutch service door sensor **72** to the noninverting input of comparators **122, 122''**. The R/C filters include input resistors **116, 116'** and capacitors **118, 118'**. The output of the R/C filters is connected to the anode of respective biasing diodes **120, 120'**, the cathode of which is connected to a +5 volt supply source. The noninverting input of the comparators **122, 122'** is connected to a +2.5 volt supply source. The output of the comparators **122, 122'** is connected to the input of respective operational amplifier buffers **126, 126'** and to pull-up resistors **124, 124'**, which are in turn connected to the +5 volt supply source. The output of the operational amplifiers **126, 126'** are connected to respective output filter circuits having input resistors **128, 128'** and capacitors **130, 130'**. The output of these filters is delivered to an analog to digital convertor **96** prior to being delivered to the microprocessor **94**.

In the case of the kickback event signal conditioning circuit **112**, an R/C filter comprising an input resistor **116''** and a capacitor **118''** is connected from the kickback switch **70** to the input of a latch **132**. This latch holds the circuit in the last set condition, i.e. on or off, thus providing conditioned digital signals **74** suitable for input directly to the microprocessor **94**. In the above discussion the values of the voltage sources are those utilized in the preferred embodiment but can be modified to suit other circuit arrangements and components.

When a fault occurs, the microprocessor **94**, as will be later described, determines the relative urgency of the detected fault and accordingly develops either a low level warning signal **134**, or a high level warning signal **136**. The digital fault signals **134, 136** developed by the microprocessor **94** are delivered to the fault display monitor **80** by a fault signal conditioning circuit **138** comprising a latch **140** and a fault display drive circuit **142**.

INDUSTRIAL APPLICABILITY

In operation, the electronic rotary cutter control **62** sequentially controls, in a preselected order, the mechanical components of the control system **24** in response to receiving one or more of the output signals **64, 74, 76**. The logic for executing the control functions is programmed into the programmable microprocessor **94** and will be explained in more detail below.

The relationship between cutter operating modes is shown in FIG. **4**. The normal sequence for transition between modes is indicated by the flowlines having solid arrowheads. Specifically, upon powering up the system, **150**, the control enters a default/start mode **152**, designated as mode **0**, which is identical to the previously described operator selected mode **1**, i.e., the service/restart mode which is identified by the reference numeral **154** in FIG. **4**. Transition from one operating mode to another must be carried out sequentially between adjacent modes, e.g., from service/restart mode **1, 154**, to standby mode **2, 156**, or from mode **2** to operate cutter mode **3, 158** or vice versa.

If a fault is detected, the electronic cutter control **62** defaults to a condition indicated by the flowlines having open arrowheads. For example, if it is detected that the position of the service door is in any position other than closed, **160**, the electronic control will automatically default to the service/restart mode **1** until the door is closed. If a kickback event **162** is detected during normal operation, i.e., while in mode **3**, the control will default to standby mode **2**. If an internal system failure **164** is detected while in any mode, the control will default to an abort mode **166** in which all mechanical components of the control system **24** including the engine **26** are shut down. The cause of the fault or internal failure must be corrected before the electronic control **62** will permit return to normal operation.

To avoid excessive wear and prevent possible damage to the drive train components comprising the control system **24**, it is desirable to sequentially engage or disengage appropriate elements of the system. For example, to avoid unnecessary wear the brake **32** should not be applied until the clutch **28** is disengaged. For this reason time delays, identified as delays **T1** to **T5** in FIG. **5**, are included in the logic programmed into the microprocessor **94**.

By way of further example, as noted in the above remarks with respect to FIG. **4**, if the service door **78** should open during operation of the cutter i.e., mode **3**, the electronic cutter control **62** will automatically default to service/restart mode **1**. As shown in FIG. **5**, the solenoid actuated clutch control valve **42** is immediately deactivated without any time delay, thereby disengaging the clutch **28**. After a predesignated time delay, identified as **T5**, to permit the clutch pistons to be purged, the solenoid actuated brake control valve **44** is energized thereby applying the brake **32**, and the solenoid actuated belt tensioner control valve **46** is deactivated thereby releasing tension on the belt **38** and applying the auxiliary brake **58**. The actual length of the time delays T1 to T5 will depend on the size and characteristics of the particular mechanical components, but typically are on the order of **1** to **5** seconds.

Preferably the programmable microprocessor **94** is programmed according to the logic sequences shown in FIGS. **6** through **14**. In addition to the programmed instructions illustrated in the flowcharts, the microprocessor **94** is accessed to one or more look-up tables **144**, **146** providing reference values for system generated signals such as the pulse width modulated signals **64**, **76**.

It should be noted that the primary cutter command program **168**, illustrated in FIG. **6**, is part of a computational loop or caller **170** that first determines if the cutter module is ready, as indicated by decision box **171**, and if not, executes the diagnostics routine **172** shown in FIG. 7. The diagnostics routine checks for faults that must be corrected before proceeding with execution of the primary cutter control module. If the service door position sensor **72** indicates that the door **78** is open, represented by the decision box **174**, a command **176** is given to execute the access door handler subroutine **178** shown in FIG. 12.

The access door handler **178** resets all of the delay counters, **180**, and issues a command **182** to disengage the clutch. If the system is not currently in a power-up sequence **184**, the program checks to determine if the clutch pistons are disengaged **186**. This determination is made affirmatively if the time delay (T5) has expired. If the system is in a power-up sequence, the clutch will already be disengaged, and the time delay requirement will be bypassed. After being assured that the clutch is disengaged, commands **188**, **190** are given to respectively engage the brake and release the belt tensioner. A command **192** is then executed which sends a high level warning signal **136** with an identifying error code indicating that the access door is open to the fault display monitor **80**. Execution is then returned to the caller **170** for reexecution of the aforementioned routines until the cutter door is closed, at which time the cutter door status inquiry **174** in the diagnostics routine **172** is answered negatively.

After determining that the cutter door is not open, the diagnostics routine **172**, as shown in FIG. 7, checks for the presence of an internal system failure **194**. If an internal system failure is detected, such as the unintended or abnormal functioning of a component internal to the system, e.g., a short or an open circuit, or as a result of a command developed by one of the subroutines to be subsequently described, a command **196** is given to execute the internal system failure handler **200** shown in FIG. 13. The internal system failure program executes a series of commands, **202**, **204**, **206**, **208**, **210**, to respectively reset all delay counters, shut down the engine, disengage the clutch, engage the brake, and release the belt tensioner. A command **212** is also executed which sends a high level warning signal **136** with an identifying error code indicating an internal system failure to the fault display monitor **80**. Execution is then returned to the caller **170** for reexecution of the aforementioned cutter and diagnostics routines **168**, **172** until the internal failure is corrected. Therefore, either an open access panel or an internal failure will result in a command to return to the caller **170**. This condition, is indicated in FIG. 7 by the action box **214**, clutch module = not ready.

After correction of an internal system failure, or in the absence of such failure, diagnostics routine **172** proceeds to determine if the current mode of operation is the cutter operate mode, i.e., mode **3**, as indicated by the decision box **216**. If the mode of operation is Mode **3**, an inquiry **218** is made to determine if a kickback event is detected.

If a kickback event is sensed, a command **220** is given to execute the kickback handler **222** shown in FIG. **14**. The kickback handler program **222** issues a command **224** to disengage the clutch and then, after determining that the clutch pistons are purged **226**, i.e., that the time delay (T4) has been satisfied, a command **228** is given to engage the brake. A command **230** is also executed which develops a high level warning signal **136** with an identifying error code indicating the presence of a kickback event and delivers the warning and code to the fault display monitor **80**. Execution is returned to the caller **170** until the kickback fault condition is corrected.

Referring again to the diagnostics routine shown in FIG. 7, if the cutter door status inquiry **174**, the internal system inquiry **194**, the mode **3** operation inquiry **216** and the kickback event inquiry **218** all have a negative response, the conditions of the diagnostics routine **172** have been satisfied and the cutter module is in a ready condition as indicated by the action box **230**. The diagnostics routine **172** thereby repetitively monitors system failure and fault signals and develops and executes output signals to control operation of the rotary cutter **20**.

Turning again to FIG. **6**, when an affirmative response is received from the diagnostics routine, i.e., cutter module is ready, the cutter program **168** proceeds to determine, as indicated by decision box **32**, if the default/start mode has successfully executed. If the default/start mode has not been successfully executed, a command **234** is given to execute the default handler **236** described in FIG. **8**.

The default handler **236** turns on the main power relay, **238**, disengages the clutch, **240**, and after a predetermined time delay (T1), **242**, applies the brake, **244**. Following a second time delay (T2), **246**, a command **248** is given to release the belt tensioner **40** and apply the auxiliary brake **58**. If the mode selector switch **66** is set at the service/restart mode **1** position, as indicated by the decision box **250**, the default routine has been successfully executed and the mode of operation is set as mode **0**, as shown in action box **252**, and execution returns to the caller **170**. If the mode selector switch **66** is set at a position other than the mode **1** service/restart position, a low level warning signal **134**, represented by the action box **254**, is developed by the microprocessor **94** and delivered to the fault display **80**. Exit from the diagnostics routine cannot be completed until the mode selector switch is set to the mode **1** position.

After the diagnostics and default routines, **172**, **236**, have been successfully executed, the cutter program **168** proceeds to determine, as represented by the decision box **256** (FIG. **6**), if the present mode of operation is being executed. If the response to this determination is negative, a command **258** is given to read the mode of operation from the a temporary cutter mode table or from the cutter mode selector switch. If the response to the inquiry regarding execution of the present mode of operation is affirmative, a command **260** is given to update the cutter mode table. The operating mode information **258**, **260**, developed in the response to the inquiry **256** regarding present mode execution status, is then compared, as indicated by decision box **262**, with the mode selected by the operator, i.e., the position of the mode selector switch **66**. If the present operating mode and the position of the operator controlled mode position switch correlate, the program returns to the caller **170** for reexecution of the cutter routine **168**. If the mode selected by the operator does not agree with the present operational mode, a comparison **264** is made to see if the mode selector switch is at position **1**, the service/restart position. If, at this point, the mode selector switch **66** is at position **1**, a command **266** is given to execute the service/restart subroutine **268** shown in FIG. **9**.

The service/restart subroutine **268** begins by determining, as indicated by the decision box **270**, if the transition to this mode (mode **1**) was from the default mode. If affirmative, the exit status of the cutter drive components is summarized in information box **272**, and a first command **274** is given to remove the warning and error code from the fault display. This is then followed by a second command **276** to set the mode of operation in the temporary cutter mode table at mode **1**, and execution is returned to the caller **170**. If the transition to the service restart mode was not from the default mode, a determination is made, as shown by decision box **278**, if the transition was from position **2**, the standby mode. If affirmative, the exit status of the cutter drive components is summarized in information box **280**, and a command **282** is given to place the drive components in service/restart mode, i.e., with the auxiliary brake engaged and the belt tension released, prior to setting the mode of operation at mode **1**, as indicated by the command box **276** and returning execution to the caller **170**. If transition to the service/restart mode was not from the default or standby modes, an internal system failure command **284** is developed, followed by return to the caller whereupon the failure command thus developed signals the diagnostics routine **172** (FIG. **7**) to execute the previously described internal system failure handler **200** (FIG. **13**).

Turning again to FIG. **6**, if the modē of operation does not agree with the position of the mode switch, and the mode switch is not at position **1**, a determination is made, as indicated by decision box **6**, if the mode selector switch is in position **2**, the cutter standby mode. If affirmative, a command **288** is given to execute the cutter standby subroutine **290**, shown in FIG. **10**.

The cutter standby mode **290** begins by determining, as indicated by the decision box **292**, if the transition to this mode (mode **2**) was from the cutter operate mode (mode **3**). If affirmative, the exit status of the cutter operate mode is summarized in information box **294** and a command **296** is given to disengage the clutch. Until a predetermined time delay (T4) has elapsed, indicated by the decision box **98**, a command **300** is given to generate an internal flag that the present mode of operation is still being executed, and execution is returned to the caller **170**. After it is determined that the clutch pistons have been purged, i.e., after the time delay (T4), a command **302** is given to engage the brake, followed by commands **304**, **306** to respectively update the cutter mode table to reflect that the mode of operation is now mode **2**, and issue an internal flag that transition to the present mode of operation has been successfully completed, prior to returning execution to the caller **170**. If transition to the cutter standby mode was not from the operate mode (mode **3**), a determination **308** is made if the transition was from the service/restart mode (mode **1**). If affirmative, the exit status of the cutter drive components are summarized in information box **310**, and a command **312** is given to release the auxiliary brake and engage the belt tensioner, after which the previously described commands **304**, **306** to respectively update the cutter mode table and issue an internal flag indicating that there has been a successful transition to the present mode are generated. If transition to the cutter standby mode was not from mode **3** or mode **1**, an internal system failure command **314** is developed, followed by a return to the caller **170** for execution of the internal system failure handler **200** (FIG. **13**) as described above.

Turning once again to FIG. **6**, if the mode of operation does not agree with the position of the mode switch, and the mode switch is not set at position **1** or position **2**, a determination is made, as indicated by the decision box **316** if the mode selector switch is set at position **3**, the operate cutter mode. If affirmative, a command **318** is given to execute the cutter standby routine **320** shown in FIG. **11**.

The operate cutter routine **320** begins by determining, as indicated by the decision box **322**, if the transition to mode **3** was from the cutter standby mode (mode **2**). If affirmative, the exit status of the cutter drive components, i.e., the status of the components while operating in mode **2**, is summarized in information box **324** and a command **326** is developed to release the brake. Until a predetermined time delay (T3) has elapsed, indicated by the decision box **328**, a command **330** is given to set an internal flag indicating that the present mode of operation is still being executed, and execution if returned to the caller **170**. After it is determined that the brake pistons have been purged, i.e., after the time delay (T3), a command **332** is given to engage the clutch, followed by commands **334**, **336** to respectively update the cutter mode table and set and internal flag indicating that transition to the operate mode has been successfully carried out, prior to returning execution to the caller **170**. If transition to the cutter operate mode (mode **3**) was not from the cutter standby mode (mode **2**), an internal system failure command **338** is developed, followed by return to the caller **170** whereupon, in the previously described manner, the internal failure routine **200** (FIG. **13**) is executed.

Turning still once more to FIG. **6**, if the cutter program **168** fails to initiate the transition to, or continuation in, an operator selected operating mode, an internal system failure is indicated, whereupon a command **340** is developed. After return to the caller **170** and subsequent reexecution of the cutter module ready inquiry **171**, execution is directed to the diagnostics routine **172** (FIG. **7**) to carry out, in the above described manner, the internal system failure routine **200** shown in FIG. **13**. As noted earlier, execution of the internal system failure routine places the cutter drive components in the abort mode and delivers a high level warning signal **136** to the fault display monitor **80**.

Furthermore, as illustrated by the flowcharts shown in FIGS. **6** through **14** and the above description of the flowcharts, it can be seen that the control system software routinely examines all inputs and outputs to ensure that internal system failures and preselected external fault conditions do not go undetected. Whenever internal failures occur, the system immediately goes to an abort mode, ensuring that all actuators in the system have been turned off, and a return to, or initiation of, normal operation is prevented until the failure has been corrected. When a fault condition is detected, the system immediately reverts to an appropriate lower operating state and remains at such state until the fault condition is corrected.

For these reasons, the preferred embodiment of the present invention includes an auxiliary brake **58** that is automatically engaged in the abort mode. Furthermore, the auxiliary brake **58** will also be engaged, and belt tension released, whenever electrical power to the control is interrupted or there is a loss of hydraulic pressure. This arrangement is particularly advantageous whenever the road planer **10** is shut down for service or during periods of nonoperation, such as overnight, thereby extending the service life of the endless belt **38**.

Thus, the present invention provides a control system for a rotary cutter in which the mechanical drive components are selectively and sequentially controlled in response to operator inputs and to sensed operating conditions. The control responds to the occurrence of predefined fault events and internal system failures by controlling the operation of one or more of the mechanical drive line components in a preselected order. Furthermore, suitable time delays are provided between the execution of selected commands to prevent undesirable wear or loads on components of the drive train.

The rotary cutter control logic described in the flowcharts shown in FIGS. **6** through **14** may conveniently be included as one module of a comprehensive control program that includes, in the aforementioned computational loop, control modules for vehicle steering, propulsion and other functions such as warnings and displays. The same microprocessor **94** can easily be programmed to process additional inputs, integrate the execution of the cutter, steering, propulsion, warning and display software programs, and develop control signals to support additional control functions.

Other aspects, objects and advantages of this invention can be obtained from a study of the drawings, the disclosure, and the appended claims.

We claim:

1. A control system for a road planer having a cutter rotatably mounted on said road planer, an engine operatively connected to the rotatable cutter, and at least one panel covering an access opening in said road planer, said control system comprising:

- a clutch operatively connected to said engine and having an output shaft extending therefrom;
- clutch control means for selectively engaging and disengaging said clutch;
- a brake operatively connected to the output shaft;
- brake control means for selectively applying and releasing said brake;
- a first pulley operatively connected to said output shaft;
- a second pulley connected to said rotatably mounted cutter;
- an endless belt extending between said pulleys;
- means for tensioning said belt and urging said belt into driving contact with said first and second pulleys;
- belt tensioning control means for selectively engaging and releasing said belt tensioning means;
- means for selecting one of a plurality of predetermined cutter operating modes and developing and delivering a first output signal corresponding to said selected operating mode; and,
- means for controlling preselected ones of said belt tensioning control means, brake control means and clutch control means in a preselected sequential order in response to receiving said first output signal.

2. A control system, as set forth in claim **1**, wherein said control system includes means for sensing at least one operating condition and developing and delivering a second output signal corresponding to said operating condition.

3. A control system, as set forth in claim **2**, wherein said sequentially controlling means includes a microprocessor having inputs for receiving said first and second output signals and developing and delivering first, second, and third control signals respectively to said clutch control means, said brake control means, and said belt tensioning control means.

4. A control system, as set forth in claim **2**, wherein said road planer includes a hydraulically controlled frame suspension system, and said sensing means includes a hydraulic fluid pressure switch in said hydraulically controlled frame suspension system.

5. A control system, as set forth in claim **1**, wherein said control system includes means for sensing the position of said at least one panel and developing and delivering a third output signal indicative of said panel position.

6. A control system, as set forth in claim **5**, wherein said sequentially controlling means includes a microprocessor having inputs for receiving said first and third output signals and developing and delivering first, second, and third control signals respectively to said clutch control means, said brake control means, and said belt tensioning control means.

7. A control system, as set forth in claim **1**, wherein said control system includes means for sensing a least one operating condition and developing and delivering a second output signal corresponding to said condition, and means for sensing the position of said at least one panel and developing and delivering a third output signal indicative of said panel position

8. A control system, as set forth in claim **7**, wherein said sequentially controlling means includes a microprocessor having inputs for receiving said first, second and third output signals and developing and delivering first, second and third control signals respectively to said clutch control means, said brake control means, and said belt tensioning control means.

9. A control system, as set forth in claim **1**, including an auxiliary brake interposed said brake and said first pulley and operatively connected to said output shaft.

10. A control system, as set forth in claim **9**, wherein said belt tensioning control means applies said auxiliary brake concurrently with releasing said belt tensioning means and releases said auxiliary brake concurrently with engaging said belt tensioning means.

11. A control system, as set forth in claim **1**, wherein said clutch is hydraulically actuated and said clutch control means is electrically operated.

12. A control system, as set forth in claim **1**, wherein said brake is hydraulically actuated and said brake control means is electrically operated.

13. A control system, as set forth in claim **1**, wherein said belt tensioning means includes an hydraulically actuated cylinder and said means for controlling said belt tensioning means is electrically operated.

14. A control system, as set forth in claim **9**, wherein said auxiliary brake is mechanically engaged and hydraulically released, and said controlling means of said belt tensioning means is electrically operated.

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